Report

of the

Renaissance Emerging Technologies

Action Team

Final

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Renaissance Emerging Technologies Action Team
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Introduction

This is the final report of the Renaissance Emerging Technologies Action Team. The action team was chartered by the Renaissance Systems Engineering Working Group to identify and assess emerging technologies for use in developing Renaissance architectures and in implementing generic building blocks. This introduction describes the process used to produce this report, and describes the format of the technology assessments that comprise the body of the report.

Process

The action team used the following process to produce this report:

1. Scope Definitions - The action team obtained guidance from the Renaissance Systems Engineering Working Group to define the scope of this study. The action team was directed to assess technologies that will be ready for deployment within approximately 3 years. The technologies selected should impact in some significant way the development, operations, or capabilities of Renaissance ground data systems.

2. Brainstorming - Team members brainstormed to construct a list of candidate emerging technologies.

3. Allocation - Each listed technology was allocated to a team member who served as the focal point for research and information gathering for that technology. This team member became the author for the technology assessment write-up for that technology.

4. Develop Technology Assessment Write-ups - Each author gathered material from personal research and from other individuals in his home organization, and prepared the first three sections of the assessment (as described below). Draft assessments were distributed among the team members via email, hard copy, and posting in the action team folder on the Renaissance server.

5. Critique Write-ups - Each write-up was reviewed by the team and critiqued. The review included suggestions for inclusion of missing information, especially in the maturity assessment. This process included filtering, in which some technologies were removed from the list because it became apparent that they did not fall within the defined scope.

6. Develop Recommendations - The principal author prepared recommendations for pursuit of the technology by the Renaissance project. Recommendations were reviewed by the entire action team and modified to achieve consensus.

7. Assign Priorities for Action - The priority for action for the technologies was determined by using the decision algorithm described below. Each action

team member independently plotted every technology on a Maturity vs. Impact graph. At team meetings, a consensus was achieved for the final position of the technology by discussing in depth the maturity of the technology, how it could be applied to Renaissance ground systems, and the impact that would be realized as a result of its application.

Technology Assessments

The body of this report is comprised of a set of technology assessment write-ups. The assessments are grouped into eight sections, and each assessment is assigned an identifying number for convenience. Each assessment lists the principal author(s), and was intentionally limited to 1-2 pages. Each assessment conforms to the following outline:

1. Background/Description - briefly describes the technology, and provides any background information needed to understand how it may be applied.

2. Rationale for Renaissance - describes how this technology is relevant to Renaissance ground systems. It describes why this technology has been included in this report.

3. Maturity Assessment - provides information that indicates the maturity of the technology. Two areas are discussed: available COTS (commercial off-the-shelf) and GOTS (government off-the-shelf) products that embody the technology, and current work related to this technology that is being performed at GSFC.

4. Recommended Actions - provides specific recommendations for the pursuit of this technology in the Renaissance context. These recommendations may be pursued by other Renaissance action teams, by prototypes developed and evaluated in the Renaissance SEF testbed, or by other means.

5. Priority for Action - suggests the priority for the actions described above. The priority for each technology is stated as either High, Medium, or Low. The decision algorithm used to determine the priority involved subjectively plotting the position of each technology on a 2-axis graph, where the axes are labeled Maturity and Impact. The plot of all technologies is shown at the end of this report. The plot was divided into 4 quadrants. Those technologies plotted in the upper-right quadrant (higher maturity and higher impact) were defined to have High Priority. Those technologies plotted in the lower-left quadrant (lower maturity and lower impact) were defined to have Low Priority. Technologies falling into the other quadrants were defined to have Medium Priority. Impact in this context means "relative impact on the development, operations, or capability of Renaissance ground systems". Maturity in this context means "relative maturity for application to Renaissance ground systems within approximately 3 years".

Renaissance Emerging Technologies Action Team
Technology Assessment
Ed Luczak (5/24/95)

1.1 Advanced Data Visualization Tools

1. Background / Description:

This technology allows data to be displayed in dynamic 3-dimensional formats, and allows an operator to interactively change his or her viewpoint or perspective of the data using a mouse or joystick. The ability to dynamically change the perspective of 3D data representations often allows the user to more quickly perceive patterns, relationships, or unique characteristics of the data.

Two styles of 3D data presentation can be used: physical models and abstract data representations. Physical model visualizations allow data to be displayed in the context of physical objects. For example, a 3D graphical view of a spacecraft can be used to illustrate current light/shade, temperature, and attitude data. Abstract data visualizations show data using 3D mathematical graphs or logical data structures. For example, a data visualization tool can allow a user to change his perspective and move smoothly around or above a 3D graph of telemetry data, to see around the peaks and into the valleys that may otherwise be obscured. Both of these styles of data presentation can allow the user to interact with objects in the data display. These interactions can enable the user to easily enter commands or to select subsets of data for further analysis.

2. Rationale for Renaissance:

Use of advanced data visualization technology can help operators in Renaissance MOCs and SOCs to assess situations more quickly, and to gain insight into anomalous conditions. This technology may be used to view real-time data, or to support off-line engineering analysis.

3. Maturity Assessment:

a. Example COTS/GOTS - Several sophisticated advanced data visualization tools are already available, and many additional tools are expected to appear soon. Fast workstations, large memories, and lower-cost displays are making these tools viable system components where they were previously not computationally economical. Many COTS 3-D physical model visualization tools are available that enable solids modeling, rendering and animation; the Alias 3-D Modeling and Animation System is representative of this class. GOTS tools include Space Camera (discussed below).

COTS tools for abstract 3-D data visualization include PV-WAVE, an advanced visual data analysis tool from Visual Numerics, Inc., and the Application Visualization System from AVS Inc. GOTS tools for abstract 3-D data visualization include the Cyberspace Data Monitoring System, developed at JPL. This advanced system uses a 3-D grid data representation to display real-time

telemetry data from multiple subsystems and multiple spacecraft in a concise manner. The system uses color and animation to highlight alarm conditions. Flight controllers can rotate and zoom into the grids to obtain different dimensional views of the data.

b. Current Work at GSFC - Space Camera, developed by Code 510, allows visualization of a spacecraft's position and orientation as it orbits the Earth. It has been selected for use on several GSFC missions, and has been designated a Renaissance 1st generation building block (RT-US-03).

4. Recommended Action:

a. Architecture - The 2nd generation Renaissance architecture should be designed so that a variety of data visualization tools can be added easily to MOC and SOC configurations. COTS and GOTS products are expected to be available to provide the data visualization functionality that will be useful in 2nd generation Renaissance ground systems; custom development should not be required.

b. User Interface - The 2nd generation consolidated user interface should be designed to accommodate windows generated by 3D data visualization tools, and should support the controls used to manipulate 3D views.

5. Priority for Action:

High (technology is relatively mature, and has potential for high impact on effectiveness of user interfaces).

Renaissance Emerging Technologies Action Team
Technology Assessment
Ed Luczak (5/24/95)

1.2 Hyperlinked Information Retrieval

1. Background / Description:

Hyperlinked information systems allow users to quickly navigate to related or linked information items by clicking "hot links" that are displayed in the displayed information. The hot links can be text items ("hypertext"), graphical objects ("hypergraphics"), or a combination of both. The linked information can be additional text/graphics display pages, or may be hypermedia objects such as sound files, images, graphical animations, or video. The linked-to information may be static, or dynamically generated. In many environments, this technology allows users to retrieve needed information much more rapidly and intuitively than by using traditional techniques of sequential paging or keyword searching.

2. Rationale for Renaissance:

a. Applications in the MOC - Hyperlinked information systems could be used to enhance the operational user interface of MOC and SOC systems, to enable operations personnel to perform their tasks more efficiently. Operations manuals, troubleshooting guides, and other documentation could be made accessible on-line from the MOC and SOC. This documentation could be integrated into the operations environment with "hot links" from operational software. This notion is often called "electronic documentation". This capability could be a reusable building block for Renaissance missions.

b. Applications for Remote Mission Team Members - Hyperlinked information systems could be used to easily distribute mission status information and quick-look science data to extended mission teams and scientists at many locations. This information could be automatically formatted by on-line reporting software, requiring no operator actions.

c. Applications during the Development Phase - Hyperlinked information systems could also be used to support the assembly, integration, and testing of Renaissance ground systems. The "Renaissance Capabilities Library" proposed by the Operations Engineering Working Group could be supported with this technology. Information about available building blocks and their use in specific mission configurations, mission requirements, design decisions, and integration status could be linked in an easily accessible and distributed information system using this technology.

3. Maturity Assessment:

a. Example COTS/GOTS - Many COTS now support this technology. The most wide-spread use is the World Wide Web (WWW), in which servers using Internet protocols (HTTP) provide access to hyperlinked documents that are

represented using the HyperText Markup Language (HTML). Users use client software called a "web browser" on their own workstation to retrieve and view HTML documents retrieved from "web servers". Many COTS and public domain browsers are now available, including Mosaic and NetScape. Browsers can be integrated with other application software to create applications that have browsing capabilities. Public domain and COTS server software is also widely available. COTS and public domain authoring tools that help construct or translate documents into HTML format are emerging very quickly.

Other formats for representing hyperlinked documents are also being used. Although HTML is widely used, it is evolving and not yet a real standard. Access security is still an open issue for this technology.

b. Current Work at GSFC - Many organizations at GSFC are using WWW servers to distribute project and mission information. Code 520 has an on-line catalog of division projects that includes short summaries, papers, users guides, and other information. Code 560 operates a web server for IUE project information. The Renaissance project operates a web server containing public Renaissance documents. Codes 510 and 540 have begun sharing information via web servers. Codes 600 and 900 are extensively using WWW technology to disseminate science data.

4. Recommended Action:

The 2nd generation consolidated user interface should be designed to include a generic capability for hyperlinked information retrieval. User interfaces should be designed so that operational data, electronic documentation, and application help information can be retrieved in this fashion. Principles of good user interface design should be applied to ensure that hyperlinking capabilities are used effectively. (All documentation may not be appropriate for this style of retrieval and display.)

5. Priority for Action:

Medium (technology is relatively mature, and has potential for moderate impact on effectiveness of user interfaces).

Renaissance Emerging Technologies Action Team
Technology Assessment
Haseen Uddin, Ed Luczak (5/24/95)

1.3 Multimedia (Data and Video Integration)

1. Background/Description:

The Code 500 current networking environment has multiple networks for data, video, and the associated audio. (Below we use the term video to refer to both video and its associated audio.) It is easy to observe that such an environment of distinct multiple networks is not only complex and cumbersome but also expensive to maintain. As Code 500 moves to a distributed computing environment, it becomes important to explore networking technologies that provide various types of services in an integrated fashion. This approach will reduce complexity in the near term and cost in the long term. At present, it is possible to handle data and low quality video in an integrated manner using circuit switching and packet switching simultaneously. However, the Code 500 emerging requirements for high speed packet communications and high quality video communication services will require exploring broadband technologies that have the following components:

-- coding technology for compressing vast amounts of video information
-- transmission technology for the efficient transmission of compressed video information
-- decoding technology for restoring compressed video information
-- terminal technology which integrates the above three

All four of the above areas have to be closely monitored by the Code 500 Renaissance group. However, it is the terminal technology area that must be emphasized more as it (terminal technology) has a close relationship with the attributes of the services to be provided.

2. Rationale for Renaissance:

As Code 500 moves to distributed computing , the economical provision of various information communication services with different characteristics on a single network is becoming an important challenge. The Code 500 Renaissance Group must accept this challenge (at least from the end-user's point of view).

In the near term the data and low quality video integration can take place using the already existing technologies. However, a network that can accommodate diverse forms of information media and at the same time maintain a unified access structure and transmission mode is difficult to architect with the existing technologies. The Code 500 Renaissance Group must look to the BISDN based on ATM to integrate data and high quality video.

3. Maturity Assessment:

The standards and technologies are well established for data and low quality video integration. There are multitude of products available from a large number of vendors to start at least the initial phases of video and data integration. TV, which has been the most popular mass medium up to now has not yet achieved worldwide standardization and has different signal formats around various regions around the world. However, it appears that worldwide standardization will be realized for the four areas of interest (see section 1, Background / Description) to Renaissance. SGI (Silicon Graphics Inc.), HP, Sun and others are actively involved in standard process and are developing products.

4. Recommended Action:

a. Data and Video Network Integration -

b. Multimedia User Interface - The 2nd generation consolidated user interface should support the display and control of windows containing video information. Both real-time video and replay of archived video should be supported. A MOC or SOC user should be able to select an available real-time video source, request that the video data stream be sent to his or her workstation, and have it displayed in a window. A user should also be able to select an archived video clip and replay it in a window with VCR-like controls.

5. Priority for Action (high, medium, low):

Medium (the technology for data and video network integration is still emerging, but has a high potential impact for cost effective networking for Renaissance systems)

Renaissance Emerging Technologies Action Team
Technology Assessment
Ed Luczak (5/24/95)

2.1 Expert Systems: Intelligent Mission Operations Scripting Tools

1. Background / Description:

These are new tools that are used to automate procedural operations that have time constraints. They allow users to create scripts of time-sequenced actions that can automate the interactive commanding that is today performed by Flight Operations Team members during a spacecraft pass. Scripts may include several types of tasks, including actions, decisions, and waits. These scripts can support several parallel threads of execution, to handle several concurrent operations. In addition to sequential processing, scripts also include rule-like mechanisms to allow events to be detected asynchronously. These tools usually provide a highly graphical user interface that allows an FOT member to quickly determine what the automated script is currently doing, what it has already accomplished, and what is still to be accomplished. Scripts can be built that completely automate pass operations for nominal situations, and also handle defined non-nominal situations. When an undefined non-nominal situation arises, the script can alert an operator for manual intervention. Proper script execution depends on a reliable source of time, such as is provided in MOCs.

2. Rationale for Renaissance:

These tools can be used to automate pass operations in a Renaissance MOC or SOC. They may allow operations staffing requirements to be reduced, especially in situations where an FOT team is operating several spacecraft (e.g. SMEX). A generic intelligent mission operations scripting tool could be used as a reusable building block and used on many missions.

3. Maturity Assessment:

a. Example COTS/GOTS - At least one COTS tool is available: Storm Integration's Intelligent Mission Toolkit. This product is currently being used in the Code 520 Virtual Mission Operations Center (VMOC) research project. A GOTS tool called Genie (Generic Inferential Executor) is being developed by another project in Code 520. Nearly completed, Genie will be demonstrated with the SAMPEX mission soon. Based on GenSAA, it is designed to be easily used with TPOCC missions, and is being considered for use by SAMPEX, SOHO and other missions.

b. Current Work at GSFC - Code 520 has two projects looking at this technology. The GOTS tool Genie will likely be ready for application to an early Renaissance mission such as ACE as a reusable building block. Both GOTS and COTS tools will surely be available for application in 2nd generation Renaissance MOCs.

4. Recommended Action:

Demonstrate in the Renaissance Testbed for ACE or another projected Renaissance mission.

5. Priority for Action:

High (technology is relatively mature, and has potential for high impact on the automation of mission operations).

Renaissance Emerging Technologies Action Team
Technology Assessment
Ed Luczak (5/24/95)

2.2 Expert Systems: Real-time State Modeling Tools

1. Background / Description:

These are tools that allow expert systems to be built based on state models of spacecraft and ground systems and subsystems. Each system object is defined to have nominal and non-nominal states. Telemetry and ground system status variables map into system objects; when their values change in specified ways they trigger state transitions. Problem resolution procedures are attached to non-nominal states, to handle automatic problem resolution. This approach is a model-based reasoning approach that is much superior to the rules-only approach that is typically used today. The reason for this is that much of the control structure for anomaly resolution is provided by the tool. With traditional rule-based expert systems, the developer must write rules to encode not only the problem detection and resolution knowledge, but also the anomaly resolution control structure. State modeling allows knowledge about the system and its failure modes to be structured and more easily understood.

2. Rationale for Renaissance:

Use of these tools may enable automated anomaly resolution capabilities to be much more easily built and maintained for Renaissance MOCs and SOCs. Use of state modeling tools should allow spacecraft engineers and FOT members who have detailed knowledge of the spacecraft and ground system to be closely involved in building and maintaining the anomaly resolution system. Use of these tools offers the potential for reduced operations costs due to automated support of anomaly resolution, and reduced development cost of these systems.

3. Maturity Assessment:

a. Example COTS/GOTS - This is a very new area, but at least one COTS tool is available, the Altair Mission Control System by Altair Aerospace. This tool is being used in the Renaissance 90-day COTS Ground System prototype currently under development.

b. Current Work at GSFC - Model-based reasoning approaches to building fault management expert systems have been investigated in Code 520. State modeling tools have not yet been used in operations at GSFC. The Altair tool is being used in the 90-day COTS ground system prototype being developed in the Renaissance testbed.

4. Recommended Action:

Evaluate the effectiveness of Altair COTS tool as used in the COTS ground system prototype. Determine the cost of integrating this tool into Renaissance 1st and 2nd

generation architectures. Build prototype state models for ACE or another projected Renaissance mission.

5. Priority for Action:

Medium (technology is moderately mature, and has potential for high impact on the automation of mission operations).

Renaissance Emerging Technologies Action Team
Technology Assessment
Ed Luczak (5/24/95)

2.3 Case-Based Reasoning (CBR)

1. Background / Description:

Case-based reasoning (CBR) is a relatively new way to build expert systems in which new problems are solved based on previous experience. A case is a situation that has characteristics and a solution. A case base is a collection of relevant previous problems and their solutions. When a new problem arises, the case base can be searched to find matches. If the problem has occurred before and is stored as a case in the case base, the attached solution can be used immediately. If no exact match is found, near matches are examined. Solutions in near matches can be automatically adapted with rules to more closely fit the problem at hand. Building case bases is typically much easier that building rule-based expert systems. Cases are typically placed in the case base by users, rather than system developers. The case base grows and becomes more detailed during a mission as experience is gained and operations evolve.

2. Rationale for Renaissance:

CBR can be used to help resolve anomalies in Renaissance MOCs and SOCs. CBR would be useful for identifying solutions to problems that are not sufficiently structured to handle with a state modeling approach. CBR could be used together with other anomaly resolution tools, such as rule-based systems or state modeling systems. in a Renaissance MOC or SOC. A CBR-based anomaly resolution support system could be a reusable building block. The cases in a CBR-based anomaly resolution support system for a particular Renaissance mission would be populated and maintained by the FOT.

3. Maturity Assessment:

a. Example COTS/GOTS - Several CBR COTS tools are emerging. An industry leader is Inference Corp's CBR Express. Inference is one of the most established AI tool vendors, having survived the early 90's shakeout of AI tool vendors. Inference CBR Express is being used in many industries to automate help desks, where help desk workers use the system to retrieve solutions to callers problems.

b. Current Work at GSFC - A simple prototype has been built to show how CBR can be used to help resolve data quality problems in Pacor II operations. This project is now ramping up in its next phase. CBR is also being used to build an engineering lessons learned case base in Code 504. The Inference CBR Express tool is being purchased for use in this project. CBR is also being investigated to help resolve SAMPEX anomalies. Code 513's Intelligent Command and Control (ICC) project is examining the use of CBR to accumulate a

knowledge base of actual operations experiences, and to use that knowledge in real-time decision-making.

4. Recommended Action:

Develop a low-cost prototype in the Renaissance Testbed showing how CBR can be used to build a reusable anomaly-resolution building block for Renaissance missions.

5. Priority for Action:

Medium (technology is moderately mature, and has potential for high impact on the automation of mission operations).

Renaissance Emerging Technologies Action Team
Technology Assessment
Ed Luczak (5/24/95)

2.4 Fuzzy Logic

1. Background / Description:

Fuzzy logic is a powerful extension of traditional binary logic that is based on the concept of fuzzy sets. It is used to deal with situations of partial truth - situations that are between "completely true" and "completely false". When we reason with binary logic, we reduce situations to either of two states: e.g., the temperature is hot, or it is not hot. Unfortunately, the real world is often not that simple. We often find it useful to regard the temperature as "somewhat hot" or "fairly warm". Fuzzy logic provides a simple way to quantify these types of statements, and to reason about them in very effective ways. A membership function is used to convert a numerical quantity to a "degree of membership" in a set, or "degree of truth" of a statement; e.g. 150 degrees may translate to "0.85 hot". Fuzzy expert systems are built with fuzzy rules that refer to these quantities, e.g. "If the temperature is hot, then increase the coolant flow rate". The actions of these fuzzy rules have associated membership values that are derived from the membership values of the rule's conditions. The actions are combined and "defuzzified" via another membership function to obtain a specific control action. In this way, controllers for complex environments can be constructed using simple rules.

Fuzzy logic has been widely adopted in Japan where it is being used in advanced control systems for subway trains, elevators and many consumer products. Fuzzy logic is now receiving serious attention worldwide because it provides a simple approach for building control systems that are often superior to those built with traditional methods.

2. Rationale for Renaissance:

Fuzzy logic provides a simple approach for building complex control systems. It could be applied to problems in orbit maintenance, attitude control, spacecraft subsystem control, and spacecraft instrument control. It can help automate or provide advice for some decision-making that is currently done by operations personnel.

3. Maturity Assessment:

a. Example COTS/GOTS - Tools for developing fuzzy logic systems and fuzzy expert systems are still emerging. Some tools have been developed specifically to support fuzzy logic development, such as the hardware and software tools from Togai Infralogic, Inc. Some existing tools for building expert systems are being extended to support fuzzy rules, such as FuzzyCLIPS, an extension to the GOTS expert system development tool CLIPS. Other existing tools for traditional mathematical analysis are being extended to support fuzzy logic, such as

MathWorks Inc.'s Fuzzy Logic Toolbox, which works with their MatLab and SimuLab products. The Fuzzy Logic Toolbox generates C code for control, signal-processing, and simulation applications on Unix, Windows, and Mac platforms. Logic statements and data can be described with attributes such as "warm", "fast", and "low". (Their WWW home page at http://www.mathworks.com contains fuzzy logic tutorials.)

b. Current Work at GSFC - Code 550 has used fuzzy logic to build a prototype tool that automates the planning of frequent spacecraft maneuvers that are required to maintain the orbit within several often conflicting constraints. An example rule from this system is: "If the mean orbit height is *low* and the apogee height is *not high*, then perform an apogee-raising maneuver". Membership functions are defined for low, not high, and other expressions of orbit height. The fuzzy system provides advice to flight dynamics analysts regarding when, and what type of maneuver should be performed. The prototype has been applied to the Tropical Rainfall Measurement Mission (TRMM) spacecraft, to be launched in 1997.

NASA JSC and GSFC have conducted several conferences and workshops on fuzzy logic.

4. Recommended Action:

The 2nd generation Renaissance software architecture should enable fuzzy expert systems to be modularly attached to MOC and SOC configurations to provide advice to operations personnel, or to perform automated control actions when they are so enabled.

5. Priority for Action:

Low (technology is still emerging, and has potential for moderate impact on the automation of mission operations).

Renaissance Emerging Technologies Action Team
Technology Assessment
Ed Luczak/Lew Gilstrap (5/24/95)

2.5 Neural Networks

1. Background / Description:

Neural network (NN) technology is based on the architecture of the brain: many relatively simple computing elements (neurons), each executing its own function, can cooperate to solve complex problems. A NN receives a set of inputs and generates a set of outputs. The key characteristic of a NN is that it learns from examples. It is not programmed or supplied with rules as expert system are. A NN is trained with a database of examples of the relationship between inputs and outputs that it is to provide. During the learning phase, the NN gradually learns the desired relationship between inputs and outputs. After it is trained, the NN will produce the desired outputs when it is presented a set of inputs. Much of the effort involved in developing a NN is in gathering, organizing, and checking the training data. The actual training phase itself is a minor task.

NNs are useful for a variety of different types of problems that involve recognizing patterns in data. This includes detecting anomalies in data, recognizing faulty or erroneous data records, classifying satellite imagery, forecasting, optimization, and modeling. NNs have also been used for the guidance and control of aircraft and spacecraft, and for industrial process control. NNs have been applied to practical problems for over 30 years.

2. Rationale for Renaissance:

NNs can help in the real-time or off-line detection of anomalies in Renaissance MOCs and SOCs. They can help automate anomaly detection and analysis operations that are currently performed manually or with limited software support. JSC has designed their new Mission Control Center software to enable NNs to be added over time to monitor desired telemetry streams. An initial JSC NN application monitors voltage fluctuations on the Shuttle power bus when onboard electrical motors are turned on. The NN is trained to recognize expected and anomalous voltage fluctuation signatures. NN technology could be effectively applied to monitor a wide variety of conditions similar to this on GSFC scientific spacecraft.

3. Maturity Assessment:

a. Example COTS/GOTS - Many COTS products are available that support the development and execution of NNs. A leader in the field is the NeuralWorks product, sold by NeuralWare, Inc. Most tools are software simulations of neural networks, and run on Unix and PC platforms. Some products are available with special-purpose hardware accelerators for high-performance applications. At least one tool is available that provides advice on the NN configuration that is most suitable for a particular application.

b. Current Work at GSFC - Code 510 used neural networks in the BCAUS system, which was developed for the GRO mission. BCAUS analyzes GRO telemetry data to determine the cause of a transition to safehold mode. NNs were trained to detect patterns in the telemetry data that are relevant to the analysis. An expert system draws conclusions about the cause based on the patterns detected by the NNs.

4. Recommended Action:

The 2nd generation Renaissance architecture should be designed so that neural network tools can be easily added to MOCs and SOCs to analyze any specified data for patterns of interest. COTS products are expected to be available to provide the functionality that will be useful in 2nd generation Renaissance ground systems.

5. Priority for Action:

Medium (technology is relatively mature, and has potential for moderate impact on the automation of mission operations).

Renaissance Emerging Technologies Action Team
Technology Assessment
Curtis M. Emerson and Larry G. Hull

3.1 Common Object Request Broker Architecture (CORBA)

1. Background/Description:

Availability of low-cost workstations and growth of networking allows application processing to be spread over multiple platforms. Distributed computing has been defined as splitting a single, large or compute-intensive application over multiple platforms, or more recently, as integrating multiple applications or services into a coordinated effort.

Emphasis is being placed on Object Request Brokers (ORBs) that provide "glue" to integrate diverse heterogeneous environments and bind diverse technology. The principal function of the ORB is to manage object interactions across a network or in memory. Clients make requests for data or services. These requests are passed to the ORB which locates the requested object or service. The ORB will also return any response/result to the client object. In effect, the ORB provides what is missing in distributed computing middleware to make the network a fully distributed operating system.

Common Object Request Broker Architecture (CORBA) is the Object Management Group (OMG) standard for interoperability between object-oriented architectures. CORBA, due to the large number of vendors in the OMG, is the most widely supported ORB architecture. CORBA 1 provided the theoretical framework. CORBA 2, approved last December, provides more actual functionality.

2. Rationale for Renaissance:

Distributed computing development are of direct interest to the Renaissance. Ground systems of the future will be distributed client-server and other applications that will be interoperable and portable across a range of hardware platforms, operating systems, and network transports.

3. Maturity Assessment:

Currently available ORBs are based on CORBA 1. There are at least seven commercially available products, and two of these seven are currently available free for evaluation or research.

Interoperability between different ORB implementations is not guaranteed by CORBA and it has been widely noted that only very similar implementations of CORBA (often all from one vendor) will interoperate. Adopted in December 1994, CORBA 2 specifications from the Object Management Group are largely related to inter-ORB communications and interoperability mechanisms and are likely to spawn truly interoperable products from multiple vendors.

Unlike DCE source code which is distributed to vendors (much like X Windows source code), CORBA is a standard only. CORBA 2 products are not yet available from vendors.

4. Recommended Action:

Obtain ORB product(s), preferably compliant with CORBA 2 specification, for evaluation in SEF.

5. Priority:

Low to Medium (too early to be more precise on impact)

Renaissance Emerging Technologies Action Team
Technology Assessment
Larry G. Hull

3.2 Distributed Computing Environment (DCE)

1. Background/Description:

Distributed Computing Environment (DCE) is the Open System Foundation (OSF) attempt to provides the facilities for defining distributed client-server applications that are interoperable and portable across a range of hardware platforms, operating systems, and network transports. DCE includes a number of services, such as security, time, naming, and management, and is based on the Remote Procedure Call (RPC).

Unlike CORBA which is a standard only, DCE is source code which is distributed to vendors (much like X Windows source code), so the DCE versions sold by each vendor are highly similar, giving the user a high degree of interoperability and portability.

2. Rationale for Renaissance:

Distributed computing development are of direct interest to the Renaissance. Ground systems of the future will be distributed client-server applications that are interoperable and portable across a range of hardware platforms, operating systems, and network transports.

3. Maturity Assessment:

Work with DCE is currently underway within the Renaissance. The System Engineering Facility is actively seeking to understand the DCE technology, including such things as:

- **DCE's model for building client/server applications,**
- **the different kinds of bindings for DCE remote procedure calls (RPCs),**
- **multithreading,**
- **DCE performance.**

so as to apply this understanding to TPOCC to:

- **study TPOCC's current inter-process communication (IPC) mechanism**
- **understand the**
  - **code changes necessary to port TPOCC to DCE**
  - **changes in architecture that might be required**
  - **performance implications of the changes**
- **estimate the approximate effort in person-years that would be required to make the changes.**

4. Recommended Actions:

Continue with SEF plans to port enough of TPOCC to DCE to confirm understanding of the feasibility of and problems associated with the conversion of TPOCC to DCE.

5. Priority

High (emerged with medium-to-high impact potential)

Renaissance Emerging Technologies Action Team
Technology Assessment
Haseen Uddin

3.3 Middleware (From A Networking Perspective)

1. Background/Description:

There are several types of middleware (e.g. database, networking etc.) in existence and available on the market today. However, the emphasis here is on the communications middleware for networking. The task of a middleware package is to hide the details of communications protocols and the networking structure from applications software. In the past mainframe applications used to be tied, when required, to specific communications protocols. This made it hard to incorporate newly emerging and more efficient networking communications protocols into the applications without incurring considerable monetary and human resources.

Now that the distributed applications are becoming a norm, it has becomes important to endow applications with a new level of flexibility where the application is unaware of the communications protocol (e.g. IP, IPX etc.) and the networking environment (e.g. ONC, DCE, Socket API etc.). This kind of flexibility can be built into applications using communications middleware for networking. One of the major advantages of such an approach is that it requires no network programming expertise (it is time consuming and expensive to develop the network programming expertise specially if the task at hand is applications development) on part of the application programmers thereby reducing the application development cycle and the cost. The second major advantage is that as newer and more efficient networking protocols emerge, they may be incorporated into the existing applications (which have used communications middleware) without any modifications to the applications because it is the middleware that makes the necessary interface to the networking environment and the communications layer.

2. Rationale for Renaissance:

The distributed applications are becoming more prevalent in Code 500. Through Renaissance, the emphasis is being placed upon COTS products. However, there will still be requirements which cannot be met with COTS products. In such cases the applications software will have to be developed in-house. It is with the in-house applications development effort that communications middleware can be beneficially used to reduce the applications development cost and time.

3. Maturity Assessment:

As mentioned before, there are several types of middleware with different levels of maturity available on the market today. The communications middleware packages have started to appear on the market. The middleware is available to give applications interface into socket APIs or with the DCE. However, as these

products have not been on the market for long, the products' robustness and reliability have not been tested thoroughly. The long term prospects for the communications middleware look very good. Momentum Corp., Encompass Corp., are two of the many vendors supplying communications middleware.

4. Recommended Action:

The Renaissance testbed should test some of these products for usage in the short term.

5. Priority for Action (high, medium, low):

Medium (the technology is moderately mature, and has a high potential impact on Renaissance distributed system design)

Renaissance Emerging Technologies Action Team
Technology Assessment
Owen Kardatzke

4.1 Multithreading

1. Background/Description:

Multithreading is a term used to describe Unix applications which consist of multiple "lightweight processes". A lightweight process contains the minimum amount of information necessary to execute. In general, many lightweight processes can reside in the same address space of a process. A thread is an execution path within a process that can execute concurrently with other threads within the process.

2. Relevance to Renaissance:

The use of threads is important in the development of workstation based applications to provide the most efficient concurrent processing. Multithreading is the mechanism that DCE uses to support synchronous communication across a network. Asynchronous IPC mechanisms may rely on the server to "fork and exec" a new process for each client call. This is inherently inefficient because of the overhead of creating a new process. Multithreading allows the server to process multiple clients within a single process.

3. Maturity Assessment:

The Renaissance System Engineering Facility (SEF) is being used to evaluate DCE as a potential Renaissance environment building block. Using threads improves DCE RPC client performance by approximately a factor of 2. As the number of threads/processes increases, the relative performance of threads over processes also increases. The underlying operating system services to support multithreading are currently available on most Unix hosts.

4. Recommended Action:

Continue using the Renaissance testbed to develop and test multithreaded processes to satisfy Renaissance concurrent processing needs.

5. Priority for Action:

Medium (the technology is relatively mature, and has moderate potential impact on the cost of Renaissance systems by providing enhanced perform

Renaissance Emerging Technologies Action Team
Technology Assessment
Larry G. Hull

4.2 Software Agents

1. Background/Description:

Software developers and researchers are working to develop intelligent agents - software that can learn the habits of a user, receive instructions, and then run off to retrieve or manipulate data. While there is no clear consensus on what constitutes an intelligent agent, an agent is not just a well designed program that assists in carrying out a task. The factors needed to qualify as an intelligent agent include autonomous agency, user feedback, and conditional intelligence.

Autonomous agency means a task can be delegated to the program. Use feedback means that the agent improves over time base on user responses. Conditional intelligence means the agent can operate in complex, changing contexts that require decision making.

2. Rationale for Renaissance:

Over the next few years, Code 500 will insert increased automation and user assistance into ground systems. Given their potential for automation of operations and for materially assisting users, software agents constitute a promising emerging technology for Renaissance.

3. Maturity Assessment:

In support of advanced mission operations automation, the Software and Automation Systems Branch (Code 522) is presently investigating the development and application of agent models characterized by basic action-oriented capabilities, specialized skills, and the abilities to interact autonomously or semi-autonomously with other agents, respond to a human user's requests, and work in the background without interfering with the delegator's actions.

The agent models being investigated are designed to support a range of activities from information gathering to real-time operations support. Among the planned proof-of-concept applications are on-line and off-line flight operations support services such as Explorer Platform/Extreme Ultraviolet Explorer (EP/EUVE) report generation process; spacecraft platform and instrument Fault Detection, Isolation and Recovery (FDIR) services; and information location, retrieval, processing and presentation services.

4. Recommended Actions:

Support planned proof-of-concept applications and evaluate results.

5. Priority:

Medium (not fully emerged but with high potential for automation)

Renaissance Emerging Technologies Action Team
Technology Assessment
Owen Kardatzke

5.1 FPGA - Field Programmable Gate Arrays

1. Background/Description:

Field programmable gate arrays are the latest technology used to create high-speed circuits with off-the-shelf products. This technology provides the smallest physical element size and fastest interconnect speed. The architecture is optimized for a wide range of applications. Tools for programming these devices are optimized to speed design.

2. Rationale for Renaissance:

This technology is being target for use in telemetry processors, (frame synchronizers, Reed-Solomon decoders, and BCH decoders), for high data rate missions.

3. Maturity Assessment:

The hardware to support this technology is commercially available, along with development tools needed to customize the FPGAs for our applications. This technology could be used for near-term ground data systems with medium to high data throughput requirements.

4. Recommended Actions:

Evaluate the performance and operation of telemetry processors using this technology in the SEF.

5. Priority for Action:

High (the technology is relatively mature, and has high potential impact on Renaissance telemetry processing systems)

Renaissance Emerging Technologies Action Team
Technology Assessment
Larry G. Hull

5.2 Next Generation VLSI

1. Background/Description:

The Next Generation VLSI goal is to develop a low-cost, integrated, and transportable ground system for the acquisition of data from low-earth orbiting satellites. The system will provide all telemetry acquisition and processing functions from the antenna to user data sets. Some of the high-level specifications are as follows:

- **Receive modulated RF signals from the antenna/downconverter**
- **Output processed science data to a user network (Ethernet, ATM, FDDI, others)**
- **Perform all CCSDS AOS services**
- **Provide frame and packet processing**
- **Provide Viterbi decoding and Reed-Solomon error correction**
- **Provide uplink capability**
- **Provide-rate buffering and Level Zero Processing**
- **Generate higher level user data products**

The system will be packaged in a very low cost, Power PC (PCI Bus) platform. Also, the final end product is intended to be commercialized, to allow widespread application to both NASA and non-NASA projects

2. Rationale for Renaissance:

Low cost, highly integrated, transportable ground stations which provide both forward and return link data processing for low earth orbiting spacecraft hypothetically play a key role in the Renaissance. Specialized digital signal processing techniques provide the needed performance at over 300 Mbps. Development of Automated Control Software ties the system together and allows a user who is not an expert in the area of data systems the ability to configure and control the system to acquire science data as needed.

3. Maturity Assessment:

Code 521, Microelectronic Systems Branch, is developing a complete chip set to provide CCSDS protocol processing. These functions include frame synchronization, Reed-Solomon error correction, and service processing. Code 521 has already developed a Reed-Solomon Error Correction Chip, which operates at well over 300 Mbps. Two additional chips are currently under development, which will have similar performance. The Parallel Integrated Frame Synchronizer Chip will perform CCSDS frame synchronization at rates over 300 Mbps; the Service Processor Chip will provide all CCSDS-defined services (VCDU, Insert, VCA, bit stream, path packet, and encapsulation) at rates over 100,000 packets per second, and over 300 Mbps. A digital receiver is being developed based on

research currently being done on a parallel architecture to provide demodulation and bit synchronization. Specialized digital signal processing techniques will be implemented in a VLSI ASIC to provide performance at over 300 Mbps.

4. Recommended Actions:

Provide additional resources to accelerate development of digital receiver and data processing services. Currently, Code 520 has undertaken a cooperative approach with Code 530. Participation by other technical organizations is welcome.

5. Priority:

High (fully emerged with fairly good potential impact)

Renaissance Emerging Technologies Action Team
Technology Assessment
Owen Kardatzke (5/11/95)

5.3 Software Based Telemetry Processing

1. Background/Description:

A low cost approach to processing telemetry data without special-purpose hardware has been demonstrated in the GLOBE project by GSFC Code 564. Telemetry processing functions such as frame synchronization and Reed-Solomon error control, traditionally performed in custom hardware circuits, were developed in software and run on low cost desktop Unix workstations and portable laptop computers.

The frame synchronization process involves a bit by bit search of received telemetry data to locate the synchronization pattern. The synchronized data is then aligned to byte boundaries for subsequent processing. These first two steps require extensive bit manipulation and pose a performance challenge to a software approach.

An error detection and correction algorithm is desirable since both the return and forward link data transmissions are subject to noise interference. Because there are no provisions for duplex communication, no acknowledgment protocols are possible. The Consultative Committee for Space Data Systems (CCSDS) Recommendation For Advanced Orbiting Systems Grade-2 service provides error control using Reed-Solomon Coding and Decoding. Current systems utilize a hardware Reed-Solomon card.

Previously, the least expensive method for performing telemetry processing has been custom digital logic circuits. The processes are bit manipulation intensive. Previous trade studies comparing hardware to software showed the cost of the computer to be the key factor. The evolution of commercial computer technology has produced low cost and high performance computers. This technology is a cost effective host for software based telemetry processing.

The software algorithm posed a design and performance challenge. Adequate performance was achieved for both frame synchronization and Reed-Solomon processes using laptop and desktop computers.

Software based telemetry processing offers the advantages of portability and scaleability. Portability is a factor since all hardware cards connect via a bus and many vendors have different buses. C language software compiles and installs on all machines. Scaleability is an advantage since a wide array of commercial computer performance are available, a machine can be selected proportional to the required data rates.

2. Rationale for Renaissance:

This technology is being planned for use in telemetry processors, (frame synchronizers, Reed-Solomon decoders, and BCH decoders) for low to medium data rate missions.

3. Maturity Assessment:

The hardware to support this technology is commercially available, along with development tools needed to produce the software telemetry processing applications. This technology could be used for near-term ground data systems with low to medium data throughput requirements.

4. Recommended Actions:

Evaluate and tune the performance and operation of software based telemetry processors in the SEF.

5. Priority for Action (e.g. Low, Medium, High):

High (the technology is relatively mature, and has high potential impact on Renaissance system architecture and design)

Renaissance Emerging Technologies Action Team
Technology Assessment
Larry G. Hull

6.1 Asynchronous Transfer Mode (ATM)

1. Background/Description:

During the next several years organizations will be forced to implement networks that can adapt to the changing needs as the demand for bandwidth continues to explode (45 Mbps to 155 Mbps services). ATM (asynchronous transfer mode) has the potential to alleviate the bottlenecks in today's LANs (local area networks) and WANs (wide area networks) with a standard transmission platform that accommodates adaptation for voice, video, and data (adaptation expected to be available in '95/96 time frame).

ATM management is expected to be more decentralized, local areas will address local problems and forward appropriate events to a centralized management process for coordination. Issues being addressed by working groups include security, scale ability, and efficiency. NASA Goddard Space Flight Center is currently has a User Membership with the ATM Forum.

2. Rationale for Renaissance:

Over the next few years, Code 500 will be implementing networks that meet this demand for greater bandwidth. Given its potential to alleviate bandwidth bottlenecks with a standard off-the-shelf transmission platform, ATM is the most promising candidate for Renaissance.

3. Maturity Assessment:

LAN emulation (Ethernet, Token ring, and FDDI) and virtual networks are the keys to the near-term deployment of ATM. TCP/IP performance over ATM has to be addressed (tested). The SONET (synchronous optical network) interface seems to be emerging as the favorite ATM interface choice. (more robust framing standard, management capabilities, and compatibility between LANs and WANs). High speed chips (622 Mbps) are available and will accelerate development of ATM backbones and server connections.

Work evaluating ATM is well underway. Code 540 supports GSFC membership in the ATM Forum and Code 521, Microelectronic Systems Branch, development of an ATM Conversion System prototype.

Near term product support may be lacking.

4. Recommended Actions:

Evaluate multiple commercial sources for an ATM interface within the scope of a simulated end to end ground system environment.

5. Priority:

Low/Medium (potential impact but only just emerging and with competitors)

Renaissance Emerging Technologies Action Team
Technology Assessment
Curtis Emerson, Ed Luczak (5/24/95)

6.2 Network Firewalls

1. Background/Description:

Internet is in use at most NASA sites for administrative purposes. Many sites would also like to use Internet for operational data delivery, but are concerned about access security. Firewall network devices can secure a site from unwanted intrusion. They can be extended to also provide encryption and decryption of data.

2. Rationale for Renaissance:

The Renaissance architecture is designed to accommodate MOCs and SOCs that may be at user sites, remote from GSFC. Universities and research institutes that host MOCs and SOCs will likely want to send and receive operational data from NASA ground stations and GSFC facilities such as FDF via Internet. Firewalls can be used to enable Internet connections, while also providing the access security to prevent unwanted intrusion to these systems by other Internet users.

Nascom is migrating toward use of Internet for delivery of operational data to some NASA sites. Early adopters, however, will need to segregate and protect their Internet traffic and general network access. Firewalls may provide the access security required, but may also limit the types of access provided. Renaissance should be aware of these potential limitations.

3. Maturity Assessment:

There are at least five commercially available products. Nascom and Code 530 are in the progress of evaluating at least one product.

4. Recommended Actions:

a. Determine how firewalls can be used to enable remote Renaissance MOCs and SOCs to interact and interchange data with ground stations and GSFC facilities (e.g. FDF) via Internet, while ensuring adequate access security for the MOCs, SOCs, ground stations, and GSFC facilities.

b. Determine if any required Renaissance services and communication technologies will not be adequately supported across the Nascom firewall being considered.

5. Priority for Action:

High

Renaissance Emerging Technologies Action Team
Technology Assessment
Haseen Uddin

6.3 Wireless Data Networking

1. Background/Description

It is hard to precisely define the wireless data communications technologies. It is rather a confluence of communications, computer and consumer electronics industries which is generating products and services that allow people to establish links and exchange data without using wires. As more users become aware of the success mobile computing, they (users) have increased expectation related to access, while away from office, to their entire office environment.. To a large extent, the virtual office is becoming possible with a variety of enabling technologies that operate over wireless connections These include paging, personnel communications, electronic mail, and database access and file transfer. However improvement in software are still needed to allow mobile computing users to operate in the same manner and with the same effectiveness over wireless connections as they do when connected to the organization's wire-base information network.

2. Rationale for Renaissance

Currently, the wireless technology is being employed by organizations of all types to streamline operations, increase user satisfaction and enhance productivity. Despite its limitations, the technology has amply demonstrated its usefulness in a variety of applications. The technology is also used for mission critical data over LANs. It is primarily this area (mission critical operations) that Renaissance needs to explore fully The Renaissance team must assess the applicability and usefulness of this technology for the second generation Renaissance architecture.

3. Maturity Assessment

Over the last few years, wireless data services and applications software offerings have made significant strides that have increased user acceptance of the technology. The services include expanded local and regional coverage, roaming capability. The gateway services, which allow wireless-to-wireless users as well as wireless-to-wireline users to communicate. All indications are that wireless service providers, application software vendors and hardware vendors are cooperating to allow mobile computer users to operate in the same manner and with the same effectiveness over wireless connections as they do over wire-based networks. There are numerous vendor associations and standards organizations that are involved in developing specifications that will promote interoperability among wireless products and services.

4. Recommended Action

There are many facets of the wireless technology that are considered accepted, not emerging. For such areas (accepted technology) the Renaissance team is to look for products and services which add value to the Code 500 mission support efforts. The parts of the technology which are considered emerging (e.g. roaming, protocol standardization, reliability and security etc.) must be closely monitored and assessed.

5. Priority

Low (the technology is moderately mature, but has low potential impact on Renaissance systems)

Renaissance Emerging Technologies Action Team
Technology Assessment
David Zillig (5/24/95)

7.0 Low-Cost Communications System Alternatives: Concept Overview

1. Background/Description:

Exciting new alternatives in communications system architectures are becoming available to serve future projects, based on NASA advanced technology developments and evolving Space and Ground Network systems. These developments will allow a small satellite project to select a communications solution based on the use of:

a. Space Network only - provided by a new low-power-consumption TDRSS user transponder for TT&C operations at S-Band and a new compact TDRSS Ku-band phased array antenna for science data dumps to TDRSS at 2-3 Mb/sec.

b. Space Network/Ground Network - where the new low-power-consumption TDRSS user transponder is employed for TT&C operations via the same S-Band omni antenna used to dump science data to low-cost, receive-only ground terminals. (The use of TDRSS for command and tracking eliminates the need for transmit capability at the ground station).

In both cases, the spacecraft can be commanded on demand via the TDRSS multiple access system on a first-come, first-served basis, without previous scheduling, for mission operations and experiment control by the PI. The same TDRSS demand access service will provide continuous, near-global monitoring of return link transmissions for emergency calls or science alerts.

c. Ground Network only - provided by COTS hardware based on a low-cost ground terminal demonstration by JPL (LEO-D) and WFF (LEO-T) or on a low-cost spin-off of a receiver/exciter/ranging (RER) development by GSFC/Code 530 for STDN modernization.

2. Rationale for Renaissance:

The new communications architectures provide the potential for radical improvements in access to the spacecraft, simplified operations and reduced mission operations and ground terminal costs.

3. Maturity Assessment:

Current Work at GSFC -

4th gen TDRSS transponder	**In procurement**
Ku-Band phased array	**RFP in preparation**
Demand Access	**Under study**
LEO-T	**RFP in preparation**
GN RER	**Prototype under construction**

4. Recommended Action:

Make Renaissance projects aware of new communications operations concepts. Sponsor appropriate demonstrations for interested users in the small satellite community.

5. Priority for Action:

(See each of the following specific technologies.)

Renaissance Emerging Technologies Action Team
Technology Assessment
David Zillig (4/28/95)

7.1 Low-Cost Communications System Alternatives: 4th Generation TDRSS User Transponder

1. Background/Description:

The small satellite community is currently unable to use the Space Network due to the fact that the receiver power consumption of the 2nd and 3rd generation TDRSS user transponders is too large for the limited capacity of small satellite power systems. Codes 530 and 730 are collaborating on the development of a 4th generation transponder which is aimed at achieving a power consumption and weight comparable to the GN-only transponders currently being flown by the Small Explorer (SMEX) project. The 4th generation transponder will be an S-Band transponder capable of working with TDRSS or ground terminals. This will allow a mixed mode of operation where a project can use TDRSS for command, housekeeping telemetry and tracking and dump their high rate science data to a ground station using the same S-Band omni antenna in both modes. For users seeking a total TDRSS solution, the 4th generation transponder will provide an optional Ku-Band signal source which, together with an external Ku-Band HPA and phased array antenna, will allow a small satellite to dump 2-3Mb/sec of science data to TDRSS with roughly the same transmit power consumption as dumping to the ground.

2. Rationale for Renaissance:

When available in 1998, the 4th generation TDRSS user transponder will provide new projects with more flexible operations concepts and lower mission operations costs.

3. Maturity Assessment:

Current Work at GSFC - Procurement is currently underway for the 4th generation transponder development. The projected schedule is as follows:

Contract Award	**10/1/95**
Engineering Model	**12/1/96**
Qualification Model	**12/1/97**
Flight Unit 1	**06/1/98**
Flight Unit 2	**08/1/98**
Flight Unit 3	**10/1/98**
Flight Unit 4	**12/1/98**
Flight Unit 5	**02/1/99**

The first three flight units are committed to fly on the third series of SMEX beginning in 1999.

4. Recommended Actions:

Make Renaissance projects aware of the availability of a future low-cost, low power consumption transponder which will allow the use of TDRSS to provide more flexible operations concepts and lower life cycle costs.

5. Priority for Action:

Medium

Renaissance Emerging Technologies Action Team
Technology Assessment
David Zillig (4/28/95)

7.2 Low-Cost Communications System Alternatives: TDRSS Demand Access Communications

1. Background/Description:

Users of TDRSS theoretically have global access to their spacecraft but, in practice, must share the limited system resources by scheduling contact time, generally two weeks in advance of the service. The TDRSS multiple access system, which is capable of supporting multiple return link users, is scheduled in the same fashion as the single access system in order to share the single MA forward link. A new demand access service to be incorporated in the MA system will provide first-come, first-served access to the forward link in short intervals (to provide high availability to many users) and will provide continuous return link service. This will eliminate scheduling MA service for users, making possible more flexible operations concepts, lower mission operations costs and allow receipt of random return transmissions and service requests directly from the spacecraft whenever desired.

A key element to be added to WSC to implement this new service is an automated Demand Access Processor (DAP) which acts as an intermediary between the user project (MOCC or PI) and the WSC ground equipment to route the user's commands and configure the system or temporarily queue the service request, depending on the ongoing traffic on the system. On the return link, large numbers of users can be accommodated by increasing the number of beamformers at the White Sands ground terminal - a task which can be done cost effectively by using more modern, lower cost technology in the new beamformers.

2. Rationale for Renaissance:

The Demand Access service promises to more effectively tap the power of the global Space Network to provide exciting new possibilities for telescience and for operations concepts which are both more flexible and which offer significant opportunities for reducing the cost of mission operations.

3. Maturity Assessment:

Current Work at GSFC - GSFC successfully demonstrated demand access user service using TDRSS on January 20, 1995. The GRO and ERBS POCC's successfully sent F/L commands to their spacecraft via a prototype DAP at the WSGT and TDRS-3. ERBS had three and GRO had eight command services over two orbits with no advance scheduling by the NCC. Both spacecraft had continuous return link service throughout the demonstration.

Further concept development and system engineering are necessary before the service will be available for operational use. Expected availability is 1997.

4. Recommended Actions:

Examine the benefits of the availability of a TDRSS demand access service to Renaissance mission operations concepts and assess the associated cost savings.

5. Priority for Action:

Medium

Renaissance Emerging Technologies Action Team
Technology Assessment
David Zillig (4/28/95)

7.3 Low-Cost Communications System Alternatives: Ku-Band Phased Array Antenna

1. Background/Description:

The small satellite community, exemplified by the Small Explorers (SMEX), is currently using or planning to use a Ground Network only solution for their communications system. The Space Network was not a feasible solution for these projects due to the burden in power, volume and weight placed by the current TDRSS user hardware. A study led by Code 531 demonstrated that Space Network support was feasible provided some key technologies were addressed. A Space Network-only solution requires that the user transponder power, volume, and weight be comparable with the current SMEX transponders, that it provide a Ku-band transmitter, and the development of a Ku-band phased array. The Ku-band components will allow a small satellite to dump 2-3 Mb/sec of science data to TDRSS with roughly the same transmit power consumption as dumping to the ground. The array will electronically steer up to 30 degrees from boresight providing ample contact time with TDRSS. It will have an envelope not greater than 12" x 12" x 6" and will attach to the side of the spacecraft. GSFC/Codes 530 and 730, with support from NASA/LeRC, are collaborating on the development of this phased array.

2. Rationale for Renaissance:

When available in 1999, the Ku-band phased array, coupled with the 4th generation TDRSS user transponder, will provide flexible and low-cost Space Network-only mission operations.

3. Maturity Assessment:

The applicable technologies are considered mature and operational systems can be produced with little development and risk.

Current Work at GSFC - Codes 530 and 730 are currently drafting a Request for Proposals (RFP).

Contract Award	**4/1/96**
Engineering Model	**3/1/97**
Qualification Model	**2/1/98**
Flight Unit 1	**12/1/98**
Flight Unit 2	**2/1/99**
Flight Unit 3	**4/1/99**
Flight Unit 4	**6/1/99**
Flight Unit 5	**8/1/99**

4. Recommended Actions:

Make Renaissance projects aware of the availability of a future Ku-band phased array that, coupled with the low-cost, low-power 4th generation transponder, will allow the use of TDRSS for all their communications requirements, eliminating entirely the need for ground terminals.

5. Priority for Action:

Low

Renaissance Emerging Technologies Action Team
Technology Assessment
David Zillig (4/28/95)

7.4 Low-Cost Communications System Alternatives: Low-Cost Ground Terminals

1. Background/Description:

There is a great deal of interest from the science community in the possibility of obtaining their science data directly from the satellite at the location where it will be used. Where possible, this saves data communications costs and data delay in exchange for the cost of implementing and operating a small ground terminal or, where necessary, a network of small, low-cost terminals.

JPL recently demonstrated a low-cost, receive-only terminal called LEO-D implemented from COTS equipment. Wallops is currently preparing an RFP for a similar transmit and receive terminal called LEO-T, which will also be made up of COTS equipment.

GSFC/Code 531 has been working on the development of a receiver/exciter/ranging (RER) system to replace the aging NASA Ground Network RER used to support Shuttle. This equipment has been the workhorse of the STDN for over 25 years, supporting the majority of NASA's LEO-to-lunar missions over that period. The new receiver development is based on a unique combination of analog (CCD signal processing) and digital (COTS digital signal processing) technology which is configurable over a wide range of applications (including both GN & SN) by means of software. By using a subset of the circuit cards and appropriate firmware, a very cost-effective version of this powerful receiver can be used to implement the receive function in a low-cost ground terminal for small satellites. GSFC/531 did a receive-only demonstration in 1994 with EUVE in the TDRSS mode in the JPL/LEO-D system and tracked Shuttle during launch from White Sands in both the GN & SN modes via the TDRSS IF interface.

2. Rationale for Renaissance:

The ground terminal development and COTS equipment procurements by GSFC, JPL & WFF provide new low-cost ground terminal implementation options for small satellite projects.

3. Maturity Assessment:

Example COTS/GOTS -

JPL LEO-D - Receive-only demonstration with Sampex in 1994
WFF LEO-T - RFP in preparation for transmit & receive terminal

Current Work at GSFC -

GSFC Adv RER - GSFC/Code 531 plans to demonstrate receive-only support to SAMPEX (using a GN modulation scheme) this summer and a full receive, transmit, ranging capability for Shuttle by the end of 1995.

4. Recommended Action:

Make Renaissance projects aware of new low-cost ground terminal options. Sponsor demonstrations of desired modes of operation and support to orbital spacecraft.

5. Priority for Action:

High

Renaissance Emerging Technologies Action Team
Technology Assessment
Lew Gilstrap / Ed Luczak (5/24/95)

8.1 Agent Methods

1. Background/Description:

Agent/Domain/Task (ADT) methods are an extension of object-oriented (OO) concepts and methods which help clarify complex objects. Complex objects are simply objects that are composed of other objects in addition to having their own data and methods. The three types of complex objects most often encountered in system development are:

a. **Agents - those objects that have an easily distinguished role and for which the metaphor of "agent" is appropriate,**
b. **Domains - the "domain" (often, models of real-world domains) for which the agent is responsible, and**
c. **Tasks - the "task" or task that the agent performs on its domain of responsibility.**

When used only in a metaphorical sense, the terms "agent", "domain", and "task" are very useful in OO development because human familiarity with and intuition for these items lead to cleaner OO designs and simple and understandable system architectures. However, the great advantage of ADT methods is that agents, domains, and tasks are all objects that can be stored, retrieved, and manipulated using DBMSs, and they support the automation of every phase of system development, from domain analysis to task decomposition and to repository construction and searching.

2. Rationale for Renaissance:

The achievement of high levels of system development productivity that are required in the Renaissance era can only be accomplished by automating every phase of system development and maintenance. In the past, efforts to automate every phase of system development tended to be focused on specific phases, such as testing or coding and there were no end-to-end tools. If the items dealt with in a system development at every phase of development are all defined in a consistent manner, i.e., the are all *objects*, then it becomes very easy to develop an end-to-end automation tool. Many of the required functions are already available in ODBMSs, and the remaining functions, which include screens for the entry of data and object definitions, and screens for entering task decompositions, can be added quickly. Other automation tools such as for testing and configuration management can be added to an automation tool suite.

3. Maturity Assessment:

ADT methods actually constitute only a very small enhancement of OO methods. They are a very small evolutionary step beyond OO. All that is needed to extend OO to include ADT methods is to add the formal definitions for these objects and to

describe the ways in which they can be used in analysis, design, and implementation For system developers who are experienced in OO methods, the explanation of ADT methods takes only a few minutes. ADT methods can be applied to projects with little or no automation. Experience with limited information projects indicates that productivity gains of about 50 percent to 100 percent can be expected without automation. These are due to having cleaner designs and to basic OO methods. However, much greater productivity enhancements, perhaps as much as an order of magnitude, can result from automation of the total life cycle.

4. Recommended Action:

Include ADT methods in the collection of methods that are recommended for use in the development of future Renaissance building blocks.

5. Priority for Action:

Low (This method is still emerging, and has not yet been widely treated in the latest software engineering and OO analysis and design texts. Its impact will amplify the impact of the OO methods upon which it is based.)

Renaissance Emerging Technologies Action Team
Technology Assessment
Larry G. Hull

8.2 Document Management

1. Background/Description:

Document viewers make it easy to electronically distribute and read or print a document. Fully formatted documents appear on a variety of platforms with the fronts, graphics, and colors intact. The transmitted (or retrieved, depending on one's viewpoint) document looks and prints exactly like the original.

Issues include document accessibility, viewer availability, product usability, distribution control, document alteration, and copying. Document management is not limited to viewing. The topic overlaps both groupware (e.g., shared access, work flow), and information access (e.g., ftp, web browsers)

2. Rationale for Renaissance:

For Renaissance, Code 500 needs efficient, and effective access to the most current information and documentation. The later need can be met by documentation repositories for each organization (Division, Branch, Office), created and managed by the cognizant organization from a standard set of tools and technologies defined and provided by TIP or a TIP-like organization. These repositories would be accessible to virtually anyone within, or even outside, Code 500.

3. Maturity Assessment:

Document viewers are currently available include Acrobat (Adobe Systems), Common Ground No Hands Software), Envoy (WordPerfect), and Worldview (Interleaf). Worldview is used by the TIP On-line Library. Acrobat seems to be the most widely accepted, perhaps in part due to availability of a free document reader. These are all readily available off-the-shelf products but their proprietary nature has its drawbacks. Alternative electronic formats for documents include PostScript, RTF, and HTML.

The World-Wide Web provides exactly the kind of distributed client/server architecture envisioned for Renaissance - at little cost. Given a document repository, a WWW server that provides an on-line catalog for the database can be put up in a matter of a few weeks, possibly a few days if a full set of tools is available. A more sophisticated product requires only a bit more time and resources.

4. Recommended Actions:

TIP or an organization like TIP should be established within the System Engineering Office (Code 504) that makes tools available to the rest of the Directorate for managing documentation servers, providing client browsers and the like, and for document style templates.

Note: Netscape Corporation current and future Web products should be checked out. Microsoft may be making a free Word viewer available in the very near future. That means a Word document could be placed directly on the Web and read using this Word viewer. A lot out on the Iway has the potential to be applied directly in this area.

5. Priority

High (fairly mature with high impact potential)

Renaissance Emerging Technologies Action Team
Technology Assessment
Curtis Emerson (5/24/95)

8.3 Groupware

1. Background/Description:

Groupware is used to support collaborative work and consensus building. Applications such as electronic mail, conferencing, group decision support, shared schedules, workflow, and document management have all been referred to as "groupware".

2. Rationale for Renaissance:

Development, operation, and management of a ground support element are all team activities which require coordination among team members. It is not always possible to gather all the team members in one room at one time to address important issues. Groupware provides software (and some process) support which allows multiple people to contribute to an activity.

3. Maturity Assessment:

There are a number of tools commercially available. Most everyone uses e-mail. The STGT development contractor used DEC Notes. However, there are no interoperability standards, and the current tools may not be well integrated with other applications.

4. Recommended Actions:

Watch for tools which directly address areas of interest, or the emergence of a standard infrastructure which supports multiple tools.

5. Priority for Action:

High (the technology is relatively mature, and has a high potential impact on the Renaissance system development and integration process)

Renaissance Emerging Technologies Action Team
Technology Assessment
Ed Luczak (5/30/95)

8.4 Intelligent CASE - Simulation Tools for Integrating BuildingBlocks

1. Background / Description:

These are a new generation of CASE (computer-aided software engineering) tools that allow you to specify a system and then interactively simulate it. They are typically highly graphical and object-oriented. They allow users to model an information system using analysis and design models, and execute the model at various levels to observe system behavior and performance characteristics. This technology combines elements of several precursor technologies: traditional CASE tools, simulation tools, knowledge system tools, and code generators. Traditional CASE tools allow users to build detailed graphical analysis and design models, but these are static models that cannot be executed. Discrete event simulation tools allow users to build models of processes and systems, but are often difficult to use for simulating the details of information systems.

2. Rationale for Renaissance:

Such tools could be used in two ways to support the specification and assembly of Renaissance ground systems. First, could be used to check constraints and compatibility of reusable building blocks that are assembled into a Renaissance mission design. Second, it could be used to visually simulate the high-level behavior of Renaissance mission designs (operations concepts, data flows, etc.). Both of these functions would accelerate the process of assembling Renaissance ground data systems for specific missions.

This technology could be used to support the "Renaissance Capabilities Library" proposed by the Operations Engineering Working Group. The Capabilities Library is envisioned as a tool that helps missions determine which Renaissance building blocks are needed to satisfy the needs of their mission. As proposed, the library includes definitions of operations transactions that are supported by Renaissance building blocks, and operations scenarios taken from previous missions. Users can browse these items to determine how Renaissance building blocks could be selected and configured for their mission. An intelligent CASE/simulation tool could be used to show the dynamic behavior of these previous operations scenarios, and illustrate the behavior of a Renaissance solution to the new mission.

3. Maturity Assessment:

a. Example COTS/GOTS - There are several recently announced COTS tools that support this capability. Intellicorp's Object Management Workbench is based on the Kappa development tool. It can graphically simulate the behavior of a modeled information system, and can also generate code that actually implements portions of the system. SES/Objectbench by SES Inc. enables object

oriented analysis (OOA) models developed using the Schlaer-Mellor method to be animated to observe the behavior of the system. The behavior of system objects is simulated using finite state machines and events. Gensym's ReThink is based on the G2 real-time expert system development tool. It can animate models of information systems and business processes; it is being targeted for business process reengineering (BPR) efforts. Many other vendors are developing graphical simulation tools to support BPR.

b. Current Work at GSFC - The EOS project has examined some of these tools for system modeling and simulation. They are using animated simulation tools driven by functional models for performance modeling as part of the ESDIS Integrated Requirements Engineering System.

4. Recommended Action:

Open discussions with vendors of these tools, to better understand how close this technology is to practical realization. Obtain demonstration of tools, and evaluation copy for shake-out in the Renaissance Testbed.

5. Priority for Action:

High (technology is moderately immature, and has potential for moderate to high impact on the Renaissance system development and integration process).

Renaissance Emerging Technologies Action Team
Technology Assessment
Larry G. Hull

8.5. Pattern Languages

1. Background/Description:

Driven by the realization among software developers that they must simplify the process of building increasingly large and complex systems, an interest in patterns and pattern languages has been on the upswing. Patterns are forms that allow designers to document and share design expertise in an application independent fashion. Patterns are forms for describing architectural constructs in a way that fosters reuse. A pattern language is a set of patterns that guide one though a design. Patterns themselves have been defined as "distilled reusable knowledge".

The idea of using patterns comes from building architecture and work done to describe good architectural design. A pattern has been defined as "a rule which describes what you have to do to generate the entity which it defines." A pattern describes a solution to a problem in a given environment. Like buildings, software systems often share common elements of an architectural structure. For example, checking for a non-null pointer after allocating an object is a low-level pattern in C++. Programs which don't use such idioms often run into trouble.

"Design patterns do not provide code you can drop into your application, patterns provide experience you can drop into your head."

2. Rationale for Renaissance:

For maximum effectiveness, Renaissance building blocks need not only to be mission independent but also documented in an application independent fashion that describes the building block in a way that fosters not only its reuse but also architectural design reuse.

3. Maturity Assessment:

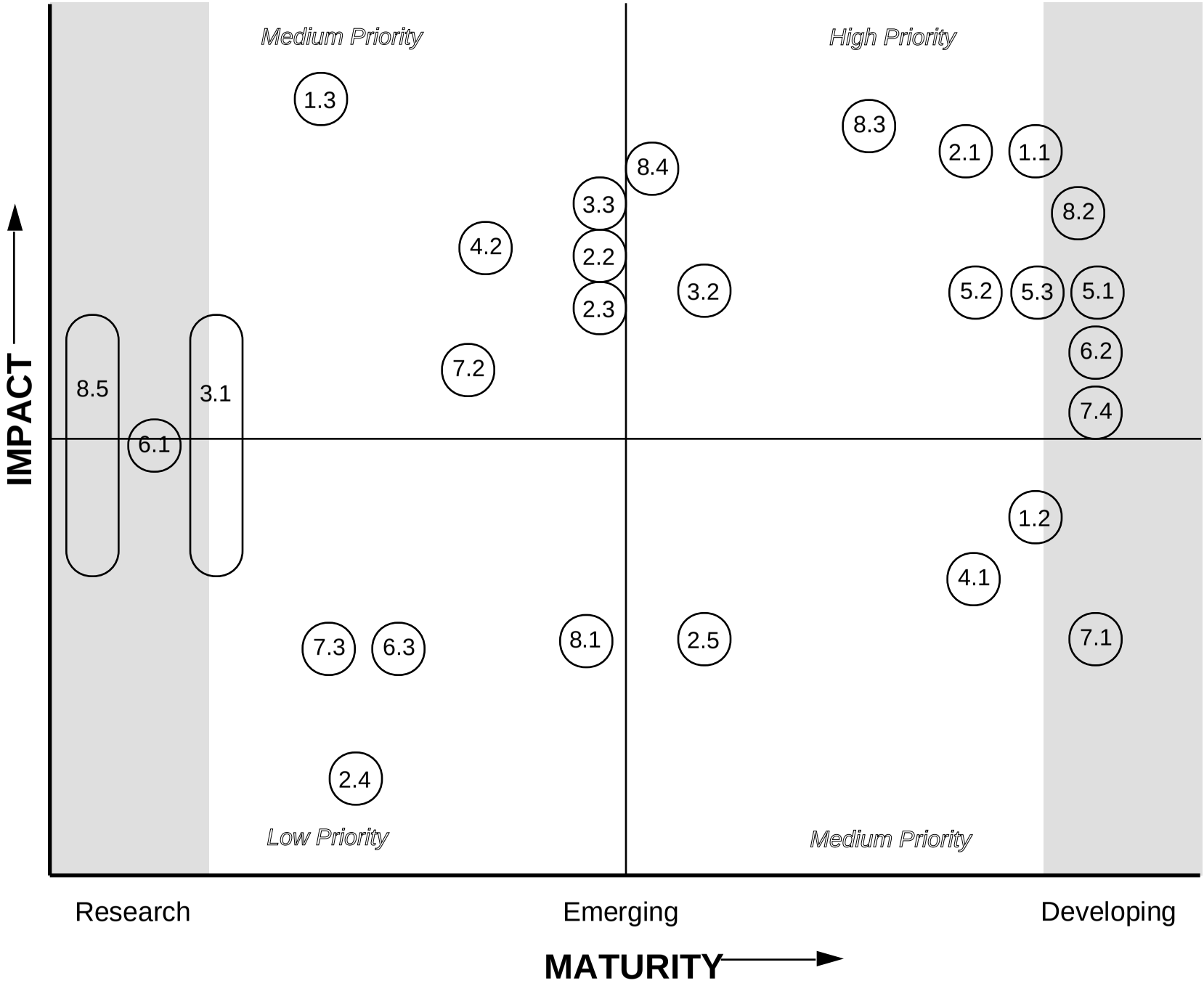
Relatively new in software, patterns are gaining visibility, applicability and momentum in the object movement.

4. Recommended Actions:

Keep abreast of the activity in this area. Evaluate the potential for Renaissance.

5. Priority

Low to Medium (potential outweighed by relative immaturity for software)


Medium Priority
High Priority
1.3
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5.3
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2.4
Low Priority
Medium Priority
IMPACT
Research
Emerging
Developing
MATURITY